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EXPERIMENTAL AERODYNAMIC ANALYSIS OF DELTA WING USING SIX COMPONENT BALANCE

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ABSTRACT

The principal idea behind the work is to determine the aerodynamic forces over a delta wing using six component strain gauge. The purpose of this experimental analysis is to collect data at various pitching moments. The information includes the Lift coefficient, drag Coefficient and pitching moment be carried out experimentally to find the forces over a delta wing model. The experiments revealed the physics behind the model with respect to the angle of the sweep angle of the current design. The results would be informative for micro air vehicles adaptability with the current design.

KEYWORDS: Lift Coefficient, Micro Air Vehicles & Sweep Angle

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Original Article

1. INTRODUCTION

Delta wings are used in many aircraft which fly at supersonic speeds. Airplanes and space planes with the delta wing oftenfly at high angles of attack, especially at takeoff or landing phases, where their aerodynamic performance at low speed is weak. Moreover, flying at high angles of attack even at tran- sonic and supersonic regimes can be expected for future space planes at the re entry phase. As the maneuverability of such aircraft is enhanced, the comprehension of the nature of unsteady flows around delta wings and the associated phenomena such as vortex breakdown and vortex-shock patterns becomes more important. It is well known that in the steady flight of a delta wing a shear layer is separated from the leading edge which produces two counter-rotating vortices on the leeside of the wing. This results in the production of large suction peaks and thereby the generation of lift. Two much smaller vortices with opposite sense of rotation relative to primary vortices, the secondary vortices, are also formed under certain flow conditions. A Delta wings are used in many aircraft which fly at supersonic speeds. Airplanes and space planes with the delta wing often fly at high angles of attack, especially at takeoff or landing phases, where their aerodynamic performance at low speed is weak. Moreover, flying at high angles of attack even at tran-sonic and supersonic regimes can be expected for future space planes at the reentry phase. As the maneuverability of such air-craft is enhanced, the comprehension of the nature of unsteady flows around delta wings and the associated phenomena such as vortex breakdown and vortex-shock patterns becomes more important. It is well known that in the steady flight of a delta wing a shear layer is separated from the leading edge which produces two counter-rotating vortices on the leeside of the wing. This results in the production of large suction peaks and thereby the generation of lift. Two much smaller vortices with opposite sense of rotation relative to primary vortices, the secondary vortices, are also formed under certain flow conditions. A Delta Wings are in use for higher speed requirements. Delta wings often fly at high angle of attack, especially during take-off and

landing mission profile it is considered that their performance is weak at low velocity. From the physics of delta wing configuration it is known fact that in steady phase delta wing will produce a shear layer separated from the leading portion of the wing which results in two counter rotating vortices shear layer is separated from the leading edge which produces two counter-rotating vortices on the aft of the wing. [6] This effect leads to the production of lift.

Delta wing plan form is a triangular shape with tips cropped. It is high sweep configuration. Delta wing is unstable usually at low speeds but some hand crafts are stable to certain extents moreover absence of horizontal stabilizer make it unstable. [3][4][10][11]Delta wing design with tip cut off is known as cropped wing as shown in figure 1 which reduce the tip drag at high angle of attacks. Cropped delta uphold lift outboard and reduce wingtip flow separation (stalling) at high angles of attack. Most deltas are cropped to at least some degree.

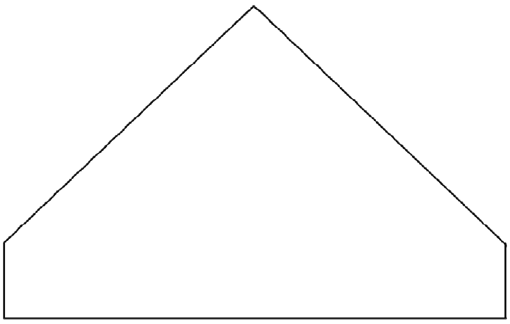

Figure 1: Cropped Delta

Figure 2: Fabricated Model of Cropped Delta

2. GEOMETRIC DETAILS OF THE WING

The cropped delta wing is modelled as sketched in figure 1. The fabricated delta wing is shown in figure 2, with a sweep angle of 53^o, with the dimensions as specified in the table 1. The model has a permanent mount integrated with type L plate for model mount and variable pitch control. The model is arranged in a way to reduce the interference effects. In the course of the test, angle of attack was varied with strain gauge component with an adjusting screw located at the bottom of the apparatus. Model is aligned with free stream and was corrected for tunnel flow angularity, No angle corrections were required for deflections of the model.

3. TESTING USING SIX COMPONENT BALANCEIN WIND TUNNEL

Wind tunnel tests are performed at Institute of Aeronautical Engineering test facility at subsonic suction type tunnel is shown in figure 3with a test section size of $60x60x2000cm^3$ model mounted on a six component strain gauge as shown in figure 4. Laminar flow is maintained across the test section with minimum turbulence levels of flow. Inclined manometer is used to measure the tunnel speed with respect to variation in the datum head. Light density manometric liquid is used low speeds to predict the variation very accurately even at very low speeds. To measure the forces and moments, data is collected for an average interval of ten for the measured values of forces and moments. Experimental methodology is adapted in the current case to extract the wing parameters at different angles of attack (AoA) and at various speeds. The model was tested at AoA of 0, 5, 10 and 15 deg with the speed range from 2m/s to 34m/s the aerodynamic parameters are evaluated in the current work.

Figure 3: Subsonic Wind Tunnel Facility at Institute of Aeronautical Engineering

Figure 4: Six Component Strain Gauge Mounted With a Delta Wing Model

4. DISCUSSIONS OF EXPERIMENTAL RESULTS

The work is to analyse experimentally cropped delta wing using wind tunnel and six component strain gauge, present work do not reflect the design philosophy, but it is adapted from the previous study[1][6][8][13]. Results of delta wing are predicted at different angles and speeds the wing surface area of 0.6m^2. Reynolds number range from 31,850 to 4,33,167, with an angle of attack from zero deg to 15 deg. From the figure 5a, 6a, 7a and 8a it is clearly evident that lift is pitching up with velocity except the case of 10 deg angle of attack and increment was linear upto 30m/s beyond which the lift has droped slightly due to separation encountered at the leading edge of the wing.

As it is generally stated that lift depends on the leading edge radius for a given Reynolds number [1][7][5]. Result graphs are presented in figure 5, 6, 7 and 8 are at AoA of zero, 5, 10 and 15 Deg. It is indicated that in figure 5b, 6b, 7b and 8b the pitching moment varies with respect to which reduced with angle of attack the trend is similar in all the cases in the current case of pitch up it is considered as negative by sign. But the resultant total drag is dependent on the lift which is raised, as proved with many theoretical relations [2] [9][12]. The drag coefficient and drag exhibited with velocity in figure 5c, 6c, 7c, and 8c and angle of attack clearly shown in figure 10 the minimum drag coefficient value at the speed range of 10m/s and the trend is very linear from the results except for 10 deg AoA which limited the maximum values at 10 deg beyond which it reduced the performance. Pitch recovery happens at a Reynolds number of 433166. Below which the magnitude of the pitching moment is very linear.

Figure 5: Delta Wing Model at Zero AoA

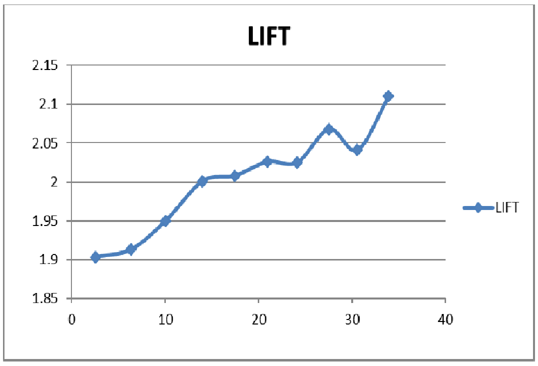

Figure 5(a): Lift Variation with Speed

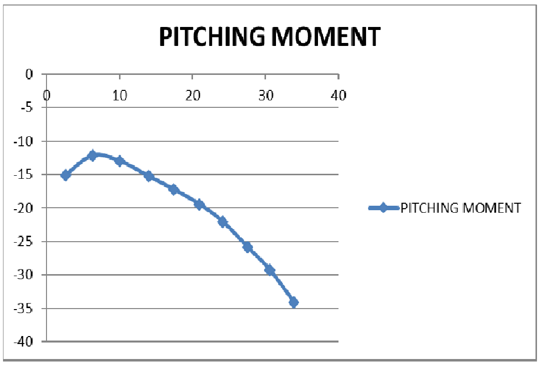

Figure 5(b): Pitching Moment Variation with Speed

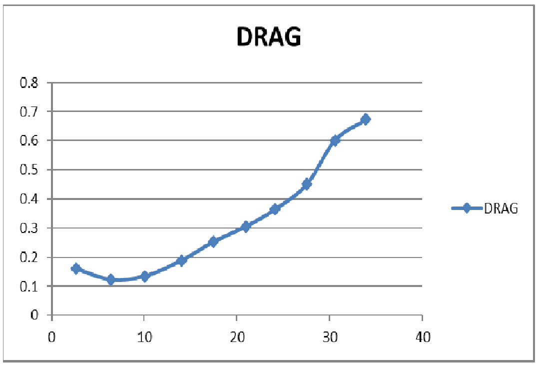

Figure 5(c): Drag Variation with Speed

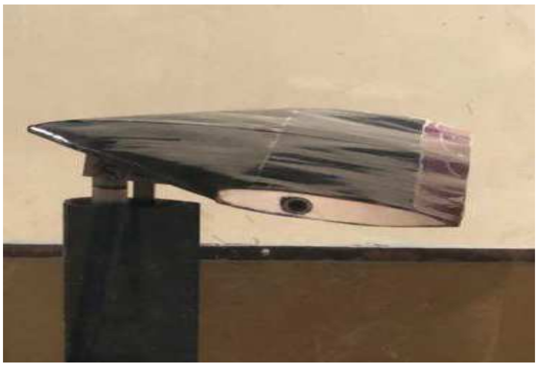

Figure 6: Delta Wing Model at 5 Deg AoA

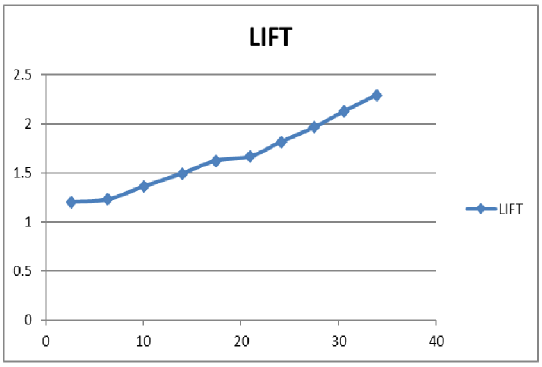

Figure 6(a): Lift Variation with Speed

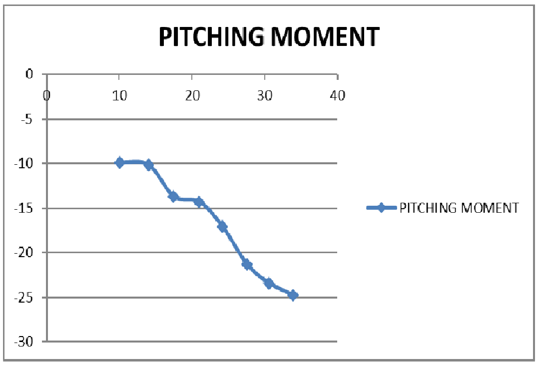

Figure 6(b): Pitching Moment Variation with Speed

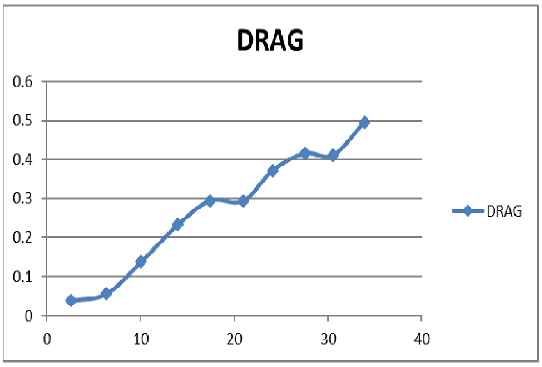

Figure 6(c): Drag Variation with Speed

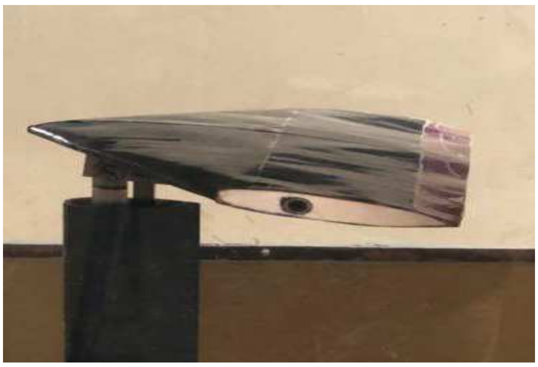

Figure 7: Delta Wing Model at 10 Deg AoA

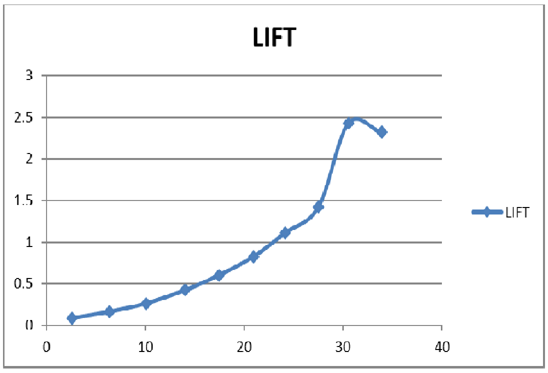

Figure 7(a): Lift Variation with Speed

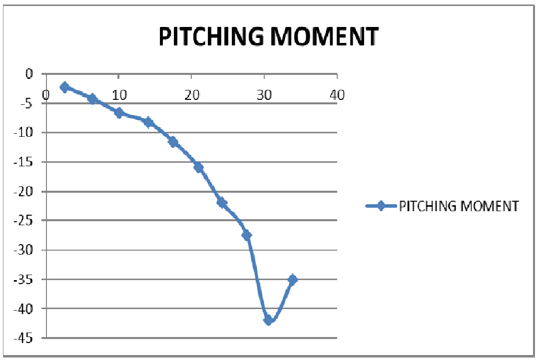

Figure 7(b): Pitching Moment Variation with Speed

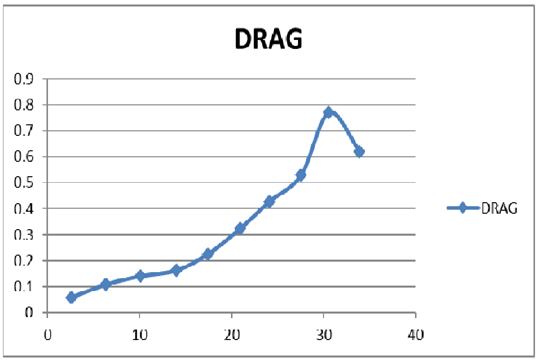

Figure 7(c): Drag Variation with Speed

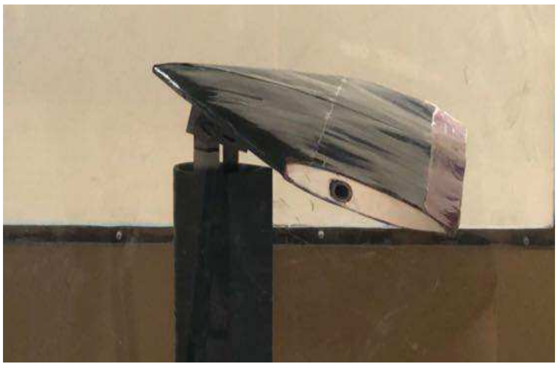

Figure 8: Delta Wing Model at 15 Deg AoA

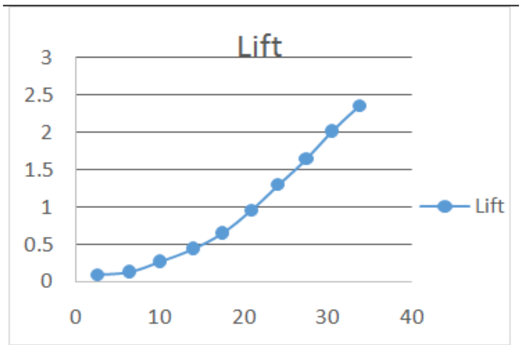

Figure 8(a): Lift Variation with Speed

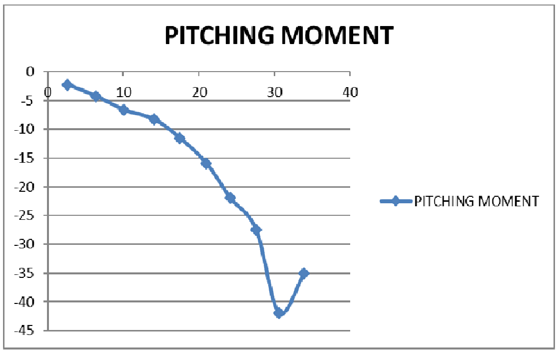

Figure 8(b): Pitching Moment Variation with Speed

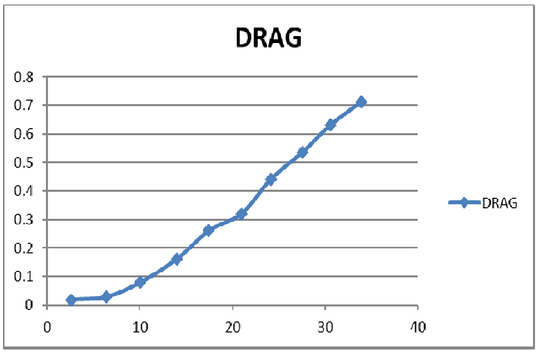

Figure 8(c): Drag Variation with Speed

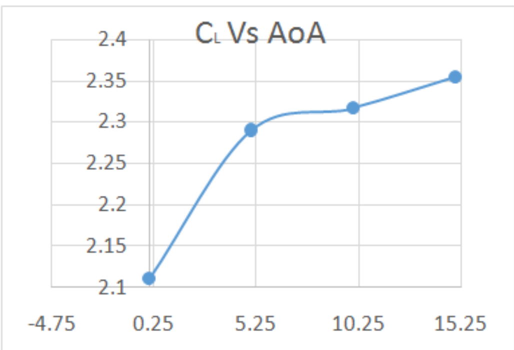

Figure 9: Coefficient of Lift with AoA

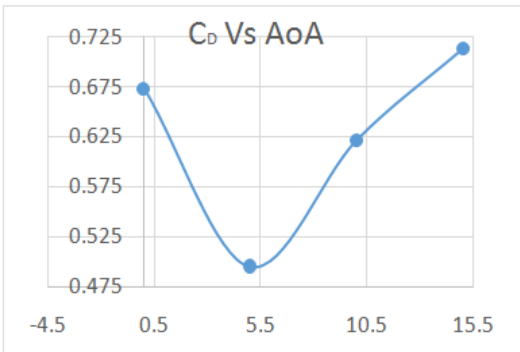

Figure 10: Drag Coefficient with AoA

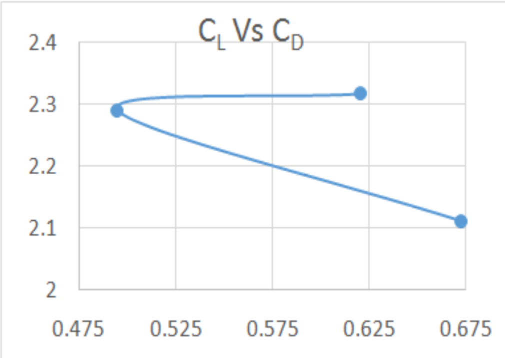

Figure 11: Coefficient of Lift with AoA

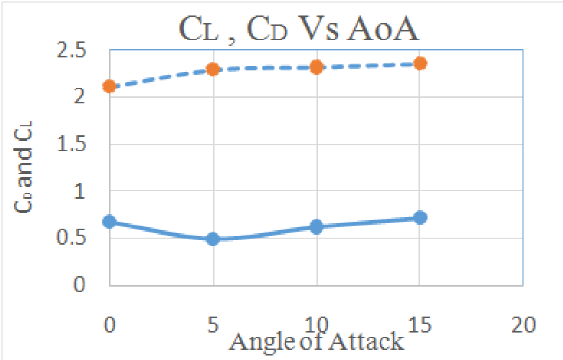

Figure 12: C_L, C_D with AoA

Table 1: Geometrical Details of Wing

Description	Dimensions
Wing root	250mm
Wing tip	112mm
Surface area	622.2mm^2
Aspect ratio	3
Sweep Angle	53 Deg

Table 2: Results at Zero Angle of Attack

Velocity (m/s)	2.6	6.37	10.07	14.01	17.45	20.97	24.13	27.53	30.56	33.9
Lift(N)	1.903	1.913	1.95	2.001	2.008	2.026	2.025	2.068	2.041	2.11
Pitching moment(N-m)	-15.08	-12.17	-12.99	-15.231	-17.207	-19.425	-22.015	-25.805	-29.221	-34.05
Drag(N)	0.161	0.123	0.135	0.189	0.253	0.306	0.365	0.451	0.602	0.673

Table 3: Results at 5 Deg Angle of Attack

Velocity (m/s)	2.6	6.37	10.07	14.01	17.45	20.97	24.13	27.53	30.56	33.9
Lift(N)	1.203	1.230	1.362	1.494	1.623	1.666	1.816	1.964	2.125	2.29
Pitching moment(N-m)	-3.381	-7.03	-9.682	-10.157	-13.690	-14.292	-17.032	-21.291	-23.412	-24.755
Drag(N)	0.038	0.056	0.138	0.233	0.294	0.293	0.372	0.415	0.41	0.495

Table 4: Results at 10 Deg Angle of Attack

Velocity (m/s)	2.6	6.37	10.07	14.01	17.45	20.97	24.13	27.53	30.56	33.9
Lift(N)	0.088	0.163	0.263	0.421	0.602	0.826	1.11	1.424	2.432	2.317
Pitching moment(N-m)	-2.218	-4.213	-6.61	-8.226	-11.502	-15.909	-21.932	-27.417	-41.932	-35.102
Drag(N)	0.059	0.108	0.14	0.163	0.226	0.325	0.428	0.529	0.769	0.621

Table 5: Results at 15 Deg Angle of Attack

Velocity (m/s)	2.6	6.37	10.07	14.01	17.45	20.97	24.13	27.53	30.56	33.9
Lift(N)	0.092	0.132	0.274	0.444	0.653	0.956	1.295	1.643	2.016	2.354
Pitching moment(N-m)	0.178	-1.782	-4.489	-8.721	-13.303	-17.512	-23.51	-28.961	-34.056	-39.64
Drag(N)	0.018	0.028	0.08	0.162	0.261	0.321	0.442	0.536	0.632	0.713

CONCLUSIONS

In conclusion of experimental results on cropped delta wing analysis at different Reynolds numbers and AoA, for the current design and fabricated model. It is clearly evident of the following facts

- This results would be very helpful for the design and performance evaluation of the wing design.
- The magnitude of the results clearly indicates the better suitability of the model with higher Reynolds number ranging from 3lakh where the regular models limits it's performance, current model can be adopted for better performance parameters and enhanced efficiency.
- The model at the higher Reynolds number exhibits sharper increment in the lift curve as compared to low Re flow and low AoA. Which indicates the vortex breakdown intensity enhancing the performance.
- Although initially drag was lowered at lower Reynolds number the trend did not follow for higher range which resulted in increment gives clear picture of vortex influence over the model.
- Cropped delta performance show diverse results from a regular model with geometric design parameters. The current results would be very useful for the UAV and MAV designs with further investigations at higher Reynolds number.

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